1904(a)
TTO OFFICE

105/CA 1226

ROHDE & SCHWARZ

MP MASTER
MA23817

BESCHREIBUNG

Current Gains

$\alpha = \frac{\beta}{1+\beta}$ $\beta = \frac{\alpha}{1-\alpha}$ $\gamma = \beta + 1$

$\alpha = \frac{dI_c}{dI_e}$ $\frac{I_c}{I_b}$ $\frac{I_e}{I_b}$

	COMM BASE	COMM EMIT	COMM COLL
		"H" PARAMETERS	
INPUT Z	hib (h_{11b})	hie (h_{11e})	hic (h''_{11c})
TRANS	hfb (h_{21b})	hfe (h_{21e})	hfc (h''_{21c})
o/p G	hob (h_{22b})	hoe (h'_{22e})	hoc (h''_{22c})
FB RATIO	hrb (h_{12b})	hre (h'_{12e})	hrc (h'_{12c})
phase relation	C.B.	no change I/P – O/P	
	CE	180° change	
	CC	no change	

Cut off freqs.

$f_\alpha = f_{C\alpha} = f_{hfb} = f_{h21}$ FOR C.B.

f_α = freqs at which α has fallen to 0.707 i.e. 6 of value at MF = DC (MF = 1Kc)

f_β FOR CE

CIRCUIT COMPARISON

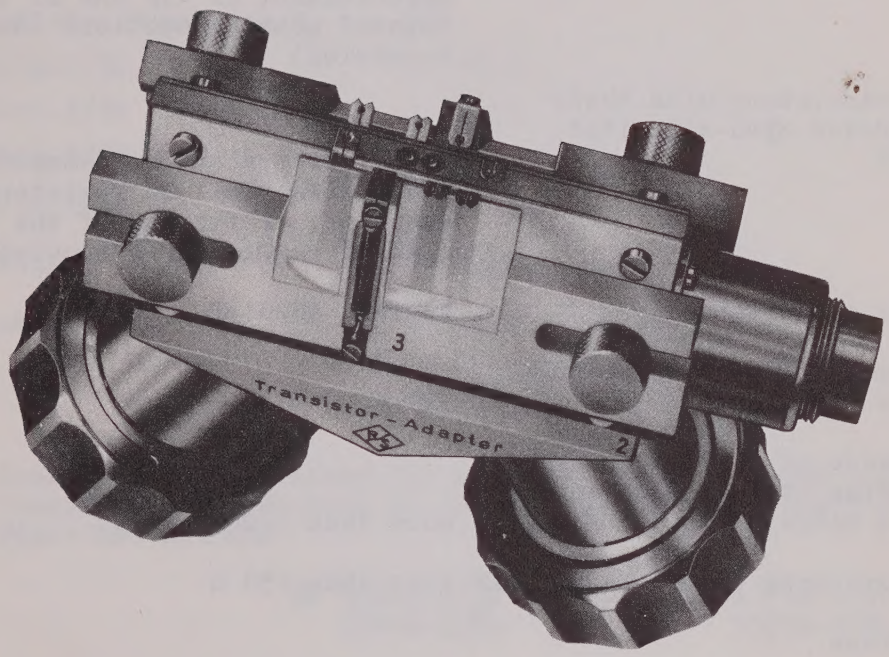
C.B.	CE	CC
I GAIN $\alpha < 1$	I GAIN $\beta \gg 1$	I GAIN $\gamma \gg 1$ ($\gamma = \beta + 1$)
I/P Z LOW	MED I/P Z	I/P Z $\rightarrow \gamma \times$ LOAD Z.
O/P Z HIGH	" O/P Z.	O/P Z $\rightarrow \frac{\text{SOURCE Z}}{\gamma}$
f_α HIGH. PHASE SHIFT	" f 180° CHANGE	f DEPENDS ON SOURCE Z.

TRANSISTOR ADAPTOR AND ACCESSORIES

BN 35616 105/CA 1226

(to be used in conjunction with the Z-g Diagraphs Types ZDU, ZDD or coaxial slotted lines)

State of development as of March 1960



Subject to change without notice · Printed in Western Germany

1. Specifications

1.1 Transistor Adaptor

Frequency range	30 to 3000 Mc
Measurable quantities	H, Y ,Z- parameters of transistors
Characteristic impedance	
BN 35616-1/50	50 Ω
BN 35616-1/60	60 Ω

Electrical length l_e of a tapered coaxial section	10.00 cm
VSWR of a tapered coaxial section	
for frequencies up to 300 Mc	less than 1.03
up to 1000 Mc	less than 1.04
up to 3000 Mc	less than 1.07
DC operating voltages	
for transistors with their electrodes short-circuited for RF	via spring contacts with lead contact lengths of 2 to 5 mm to the bypass capacitance, or via one of the two tapered coaxial sections (see accessories)
for transistors with their electrodes open-circuited for RF	selectable; via a high-impedance feed choke with small DC resistance, via a resistor, or via one of the two tapered coaxial sections (see accessories)
Bypass capacitance	approx. 4000 pf
Maximum voltage across the bypass capacitance	150 v
Impedance of the feed choke including stray capacitances in the range 30 to 200 Mc	more than 1.0 kΩ
DC resistance of the feed choke	less than 150 Ω
Connections	
for inputs and output	Precision Dezifix B
for transistors	diminutive coaxial outputs with 0.53-mm holes drilled in the centre conductors, the proper Z_o being maintained
Distance between centre conductors	3 mm
Outer diameter of diminutive coaxial output	2.72 mm
Position of the terminals for connecting the DC	adjustable
DC voltage output connector	Tuchel type FTS 60515
Dimensions	approx. 45 x 90 x 120 mm
Weight	approx. 800 g

1.2 Accessories

1.2.1 Coaxial DC Feed Section with capacitive DC separation

Frequency range	
BN 35616-2	30 to 1000 Mc
BN 35616-3	300 to 3000 Mc
Voltage across series capacitor	150 v max.
Current through feed choke	60 ma max.
Electrical length	10.00 cm ±0.1 cm
Characteristic impedance Z_o	
BN 35616-2/50	50 Ω
BN 35616-3/50	50 Ω
BN 35616-2/60	60 Ω
BN 35616-3/60	60 Ω
Connections	Precision Dezifix B+)
Dimensions	95 x 45 mm dia.
Weight	approx. 395 g

1.2.2 Coaxial reference lines for use with the Transistor Adaptor and Coaxial DC Feed Section in conjunction with the Z-g Diagraphs Types ZDU and ZDD

	BN 35616-4/50 35616-4/60	BN 35616-5/50 35616-5/60
Frequency range	30 to 3000 Mc	
Electrical length	10 cm	20 cm
Reference line for	one of the two tapered coaxial sections	the Coaxial DC Feed Section and one of the two tapered coaxial sections
Connections	Precision Dezifix B+)	
Dimensions	95 x 45 mm dia.	195 x 45 mm dia.
Weight	345 g	500 g

+) Other connections may be supplied, if desired

1.2.3 Small socket for Tuchel type connector FTD 50515 for connecting a cable supplying the DC operating voltages

Note on connectors: The transistor adaptor and the DC feed section can be provided according to our adaptable system FMU with all types of conventional connectors. However, this results in a change in electrical length. For the measurement of transistor input impedance a calibrated adjustable short with switchable connectors must be used. Transmission characteristics cannot simply be measured with connectors other than Dezifix B.

We recommend that the customers whose Z-g Diagraphs have connectors other than Dezifix B equip their instruments with Dezifix B connectors for transistor measurements. The required parts can be ordered from R&S. (When enquiring please state the serial number "F.Nr." of the set). This method has the advantage that the coaxial reference lines according to paragraph 1.2.2 can be used and that the drawbacks of undefined reference and short-circuit planes, as encountered in connectors consisting of a male and a female part, are avoided.

When fixing the Dezifix B connector, please note:

1. Check to see whether the thread of the outer conductor is fixed with a screw. If so, remove the screw.

2. Using rubber pincers or ordinary pincers and a soft lining between the jaws, carefully unscrew the outer and the inner conductor of the connector provided and insert the Dezifix parts instead.

2. Uses

When investigating high-frequency transistors for their electrical characteristics, the dimensions of coaxial connectors for the usual impedance or admittance measuring equipment are too large in comparison with the small dimensions of modern transistors. The Transistor Adaptor BN 35616-1/.. reduces the diameter of the connections to 3 mm while maintaining the characteristic impedance of the coaxial feed lines. This makes possible investigations up to several thousand megacycles, the disturbing effects of stray inductances and capacitances being practically negligible or being considered as lumped constants.

The input impedance or admittance of transistors with three or more electrodes can be measured along with their transmission characteristics in both directions, the terminating loads being selectable. It is customary to express these characteristics with H, Y or Z -parameters which are either directly measured or calculated from several known measured quantities.

It often occurs that measurements of impedance or admittance must be made where the output electrodes of the 4-terminal network must be short- or open-circuited at the high frequencies. These two special conditions can be established by means of the DC feed circuit of the Transistor Adaptor using either the bypass capacitance, the high value feed choke or a resistor. At the high frequencies and in all cases where the highest accuracy is required, the short-circuit or open-circuit condition is established by means of an adjustable short.

In order to fully utilize the advantages of the Z-g Diagraphs, it is best to use the coaxial reference lines mentioned in 1.2.2. Using these lines it is possible to eliminate, without any additional calculations, any phase shift originating in the Transistor Adaptor and/or the Coaxial DC Feed Section.

With the aid of the Transistor Adaptor, it is also possible to directly measure inductors, resistors, diodes and other small circuit elements. At higher frequencies special attention is to be paid to the best geometrical arrangement of the connecting lead.

3. Description

The Transistor Adaptor is comprised of two short sections of coaxial tapered lines joined at an angle of 50°, each line being provided with a Dezifix connector. The test item leads are inserted into the tapered ends of the centre conductors which have been provided with 0.53-mm holes drilled to a depth of 40 mm. Thus it is not necessary to cut off long leads for measurements at the high frequencies. Contact springs, which are necessary for connecting the DC operating voltages and for establishing RF short- and open-circuits, are mounted on two movable plates so that they can be brought up to a transistor electrode as required. The DC voltages are fed in via a five-contact connector.

4. Measurements

The four-terminal parameters to be investigated consist of:

(a) Impedance and admittance values ($H_{11}, H_{22}, Y_{11}, Y_{22}, Z_{11}, Z_{22}$).
These values can be measured directly with the Z-g Diagraph.

(b) Transmission parameters ($H_{21}, H_{12}, Y_{21}, Y_{12}, Z_{21}, Z_{12}$).
These values have to be worked out from the transfer constants g_B (for definition see eq. 4) forward and backward respectively and from the other values measured.

4.1 Connection of the Transistor and the Adaptor

Besides the boreholes in the centre conductors of the tapered coaxial sections, various contact springs are provided for the insertion of transistor wires, which permits the supply of DC voltages, required for the operation of the transistor. The wires with which the transistor is fixed in the adaptor should be as short as possible in order to avoid transformation of the transistor characteristics by the wires. By means of the adaptor it is possible to investigate the influence of various wire lengths on the transistor characteristics.

4.1.1 Usual Pin Base Arrangements

Generally nowadays the following arrangements are in use:

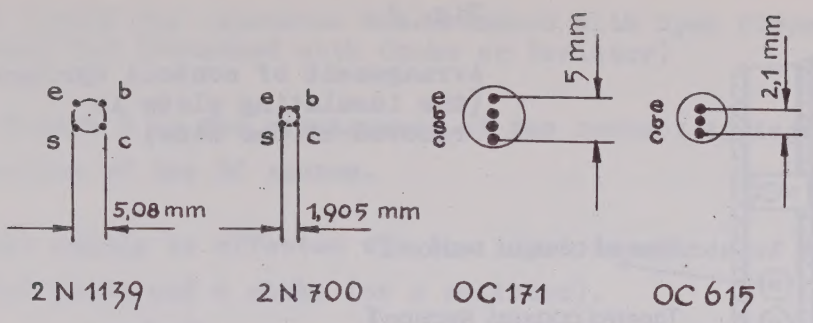


Fig. 1

In order to make the adaptor best suitable to all available socket arrangements a distance of 3 mm was chosen for the ends of the two tapered coaxial sections.

4.1.2 Arrangement of the Springs

The adaptor is provided with 8 contact springs, four on each side, which can be moved sideways with the insulation plate.

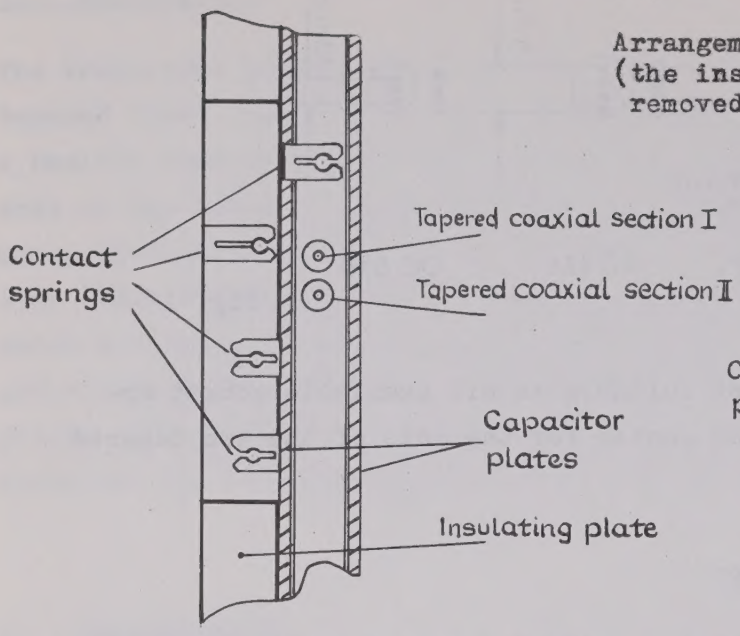
Six of the 8 springs rest on a metal plate which has a high-frequency connection to the adaptor but is isolated from it for DC. The shape of the springs provides for good contact with the capacitor plate, which makes in this way a good HF short circuit guaranting a very low resistance.

Two of the springs are mounted on a movable insulating plate and are connected with a high-valued resistor or a choke. The resistor or the choke permits, at frequencies below 250 Mc, the HF open-circuit condition to be established at the base and the emitter. The frequency limit is determined by the stray capacitances of the contact springs and of the transistor wire. When the collector is open-circuited or the frequency is higher than 250 Mc impedance measurements can only be made with an adjustable short (see 4.2.3).

While the open-circuited springs are fastened to the insulating plate, the short-circuit springs can be interchanged and fixed at any point of the insulating plate so that each of the arrangements shown in 4.2 is possible.

Fig. 2

Arrangement of contact springs
(the insulating plate is
removed at one side)



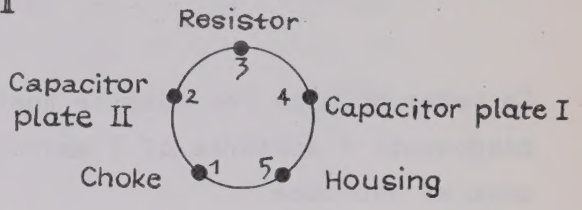


Fig. 3

Connections for the socket
looking towards the plug

4.2 DC Supply

During the measurements DC voltages have to be fed to the transistor. Since every transistor has three independent electrodes (tetrodes see 4.2.4), three points which are insulated from each other for DC and which are in connection with the transistor must exist on the adapter.

4.2.1 DC Supply for Impedance Measurements with Shorted Output (H_{11}, Y_{11})

Figure 4 shows the spring arrangement and connection of the DC voltage source. The current supply is effected via the two capacitor plates as well as via the input impedance resistor of the measuring input of the Z-g Diagraph Type ZDU/ZD

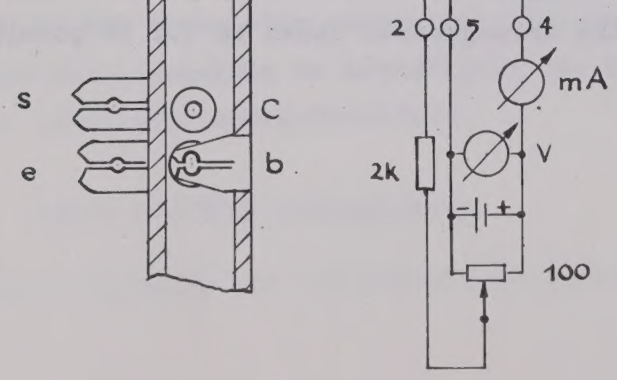


Fig. 4

Measurement of collector
impedance, with short-
circuited emitter

4.2.2 DC Supply for Impedance Measurements with Open Circuit at the Other End (Obtained with Choke or Resistor)

Shown in Figure 5 is the arrangement of the contact springs as well as the connection of the DC source.

The current supply is effected via the input impedance of the ZDU/ZDD, a capacitor plate and a choke (or a resistor).

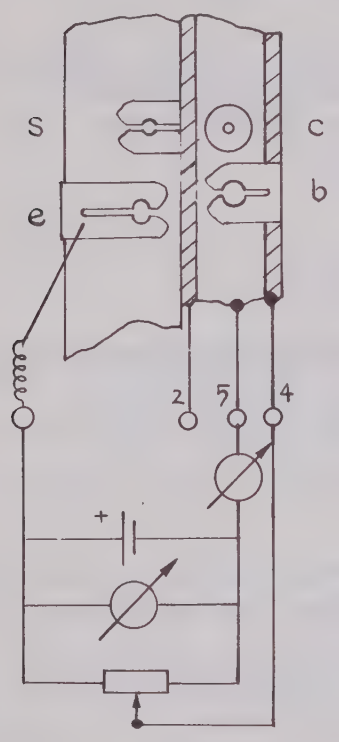


Fig. 5

Measurement of collector impedance with open-circuited emitter

e = emitter

b = base

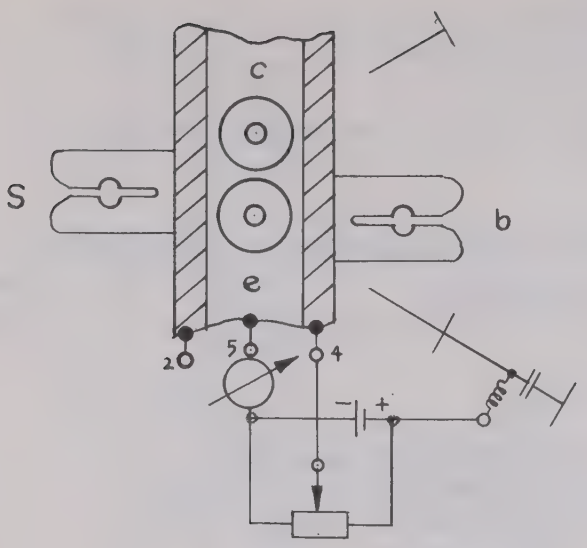
c = collector

s = shield

4.2.3 DC Supply for Impedance Measurements with Adjustable Short and for Measurement of Transfer Constant g_B (Definition see Eq. 4)

The arrangement of the contact springs and the DC source are shown in Figure 6. For measurements it is necessary to use the Coaxial DC Feed Section with capacitive DC separation as per 1.2.1 (BN 35616-2, BN 35616-3).

It is advisable to connect the Capacitive DC Separation BN 35616/.. in front of the base or emitter coaxial section because the collector impedance is so high that the small attenuation of the DC feed section could be disturbing. Care should be taken that the DC feed section is connected in such a way that the transistor and not the input impedance of the ZDU/ZDD



Tapered coaxial section I to ZDU/ZDD or adjustable short

Coaxial DC Feed Section
BN 35616/$^{-2}_{-3}$

Tapered coaxial section II to adjustable short or ZDU/ZDD, resp.

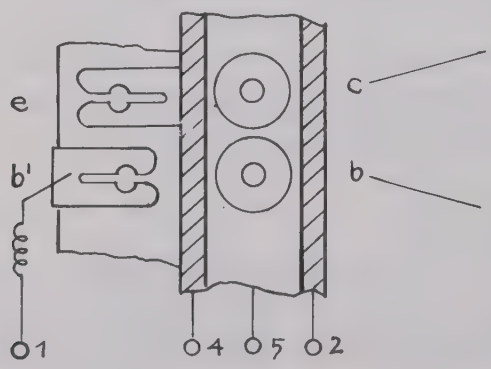
Fig. 6 Arrangement of contact springs when making measurements using an adjustable short

is supplied with DC current. The arrangement of the DC voltage path should be made with the utmost care in order not to damage the test item.

4.2.4 DC Supply when Measuring Tetrodes

Compared with simple transistors, tetrodes are provided with a further electrode which needs a bias voltage. The wire for "screening" can mostly be omitted. Therefore the DC supply can almost be set up the same way as shown in 4.2.1 to 4.2.3.

As each side is provided with an open-circuited spring contact, it is possible to arrange the transistor as shown in Figure 7.



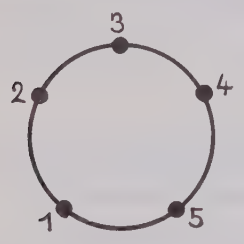
Tapered coaxial section I; ZDU/ZDD or adjustable short

Tapered coaxial section II; adjustable short or ZDD/ZDU

Fig. 7

4.2.5 Marking and Arrangement of the DC Connections

For feeding-in the DC voltages it is advisable to use the small flanged socket FTD 50515 which is supplied and to connect to it a cable ending in a multi-point connector. If this multi-point connector is marked with the same figures as the soldering lugs at the adaptor then the DC supply can be effected by means of banana plugs. That is a great advantage, especially when the type of measurement changes frequently. The position of the connections on the socket is shown in Figure 8.



Looking toward plug FTS 60515

Fig. 8

1 choke
2 capacitor plate 1
3 resistor
4 capacitor plate 2
5 housing

4.3 Measurement of the Unknown Quantities

The measuring technique with the Z-g Diagraph Type ZDU/ZDD is taken as being known. Here a few special points regarding transistor measurements will be dealt with.

4.3.1 Measurement of Impedance/Admittance

When measuring the impedance or admittance values of the transistor it is advisable to use the Coaxial Reference Lines BN 35616-4/.. as described in 1.2.2 or BN 35616-5/.. when using the adjustable short. This will eliminate the phase rotation caused by the tapered coaxial sections and the DC feed section when using the Type ZDU/ZDD. Measurements are effected according to Figure 9.

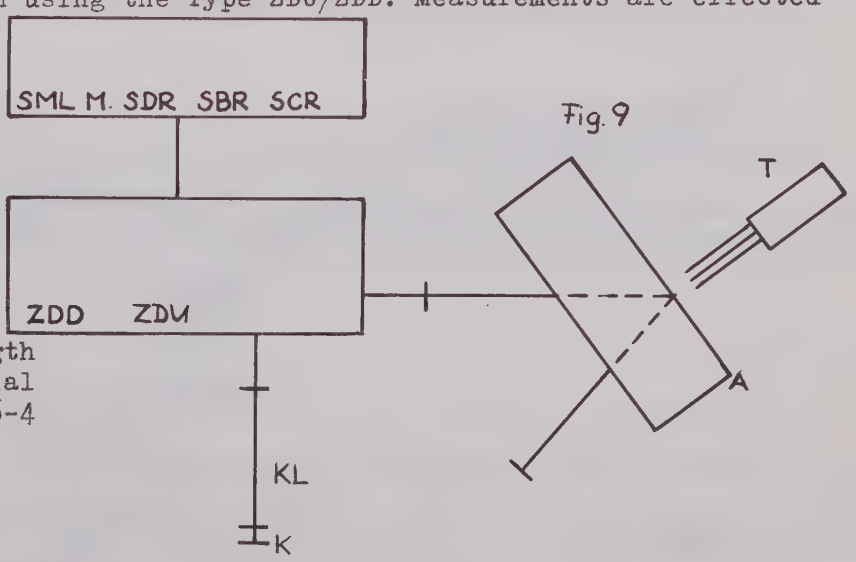
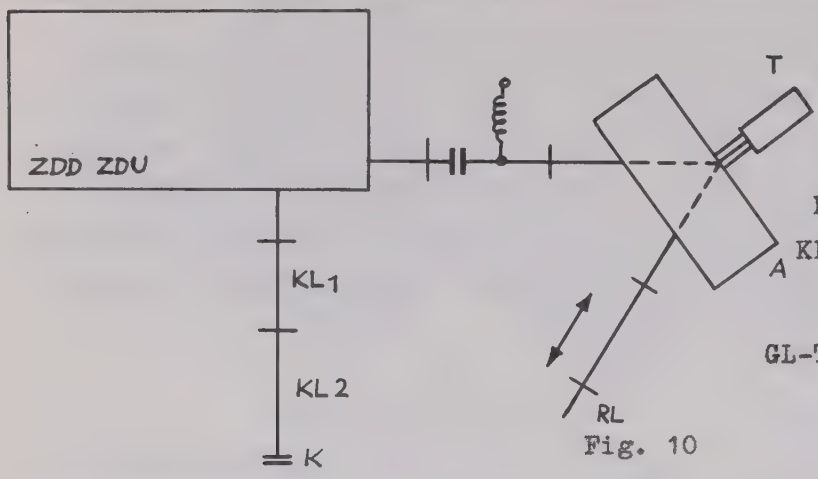


Fig. 9

K = short circuit
T = transistor
A = adaptor
KL = compensation length for adaptor coaxial section, BN 35616-4

Diagram to show the set-up for measurements with the adjustable short.



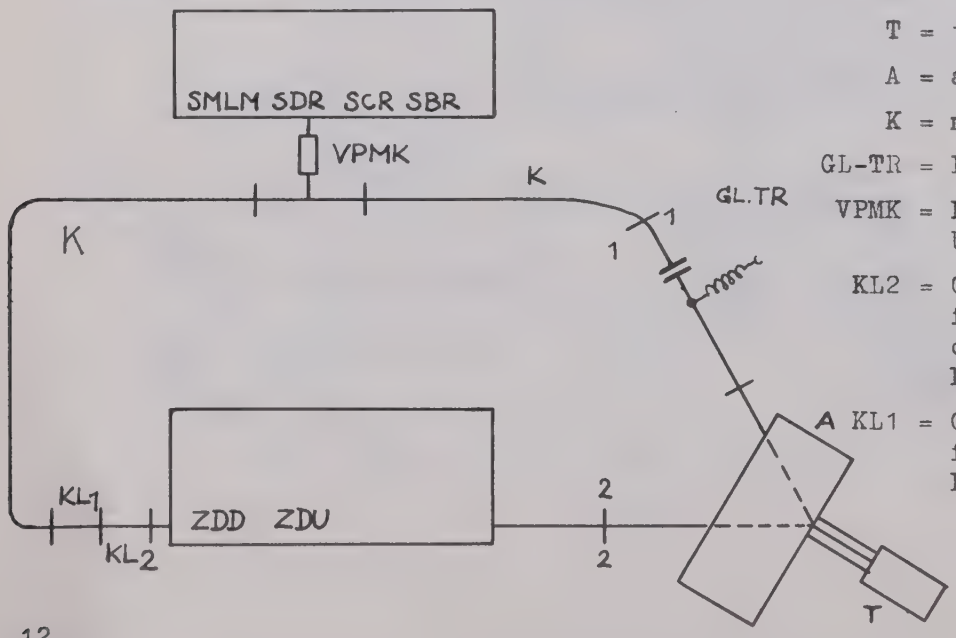
K = short circuit
T = transistor
A = adaptor
RL = adjustable short
KL2 = compensation line for adaptor and DC separation, BN 35616-5/..
GL-TR = DC separation

Fig. 10

When measurements are made with the adjustable short it should be noted that the overall length of this shorted line up to the output connector of the four-terminal network amounts to odd multiples of $\lambda/4$ (output of four-terminal network open) or to integer multiples of $\lambda/2$ (output of four-terminal network shorted); this means that the length of the adjustable short must be set by 10 cm, i.e. the length of the adaptor, shorter than the above values. The same holds true when a DC feed section (10 cm) is used at the side of the four-terminal network.

4.3.2 Measurement of the Transfer Constant (Definition see Eq. 4)

For measurement of the transfer constant you can either use a T-piece and two 20-db attenuator pads or our Four-Terminal Feed Unit for Type ZDU/ZDD 50 Ω BN 35615/550, 60 Ω BN 35614/660 and two measuring cables of the same length and characteristic impedance, 50 Ω BN 35613/50/.., 60 Ω BN 35612/.. The measurement is effected as per diagram 11:



T = transistor
A = adaptor
K = matched pair of cables
GL-TR = DC separation
VPMK = Four-Terminal Feed Unit
KL2 = Compensation line for both adaptor coaxial sections BN 35616-5/..
A KL1 = Compensation line for DC separation BN 35616-4/..

When using the Type ZDU/ZDD the two compensation lines BN 35616-4/.. and BN 35616-5/.. are necessary in order to compensate the phase rotation caused by the two adaptor coaxial sections and the Coaxial DC Feed Section.

When measuring, first balance the Diagraph to 0^{o} 0 db without compensation lengths, adaptor and DC feed section. Insert the compensation lengths, adaptor and DC feed section into the circuit and mark the measured value on the chart without varying the amplitude of the signal generator. By changing the two connectors 1.-1 and 2.-2 the transfer constant can be measured forward and backward in one operation.

4.4 Reference Plane of the Measurement

All values measured refer to the front plane of the adaptor. Between this plane and the transistor a length of wire can be inserted which is to be considered statically at low frequencies and as an inserted line at higher frequencies.

4.5 Advantages of the Measuring Method

High-frequency transistors are generally supplied with long connection wires which are shortened when being inserted into the circuit. If the transistors are measured with long wires, other values are obtained than those valid in operation. Since the tapered coaxial sections can take a wirelength of 40 mm, the specifications of a transistor with shortened connection wires can be measured.

5. Evaluation

Up to now we have only discussed the possibilities of measuring impedances, admittances and transfer constants g_B on a test item fed with DC. How does one arrive at the required four-terminal parameters from the values measured?

5.1 Positive Sign, Types of Parameters

All formulae used here refer to the symbols of diagram 12. All following values are, if not specially marked, complex.

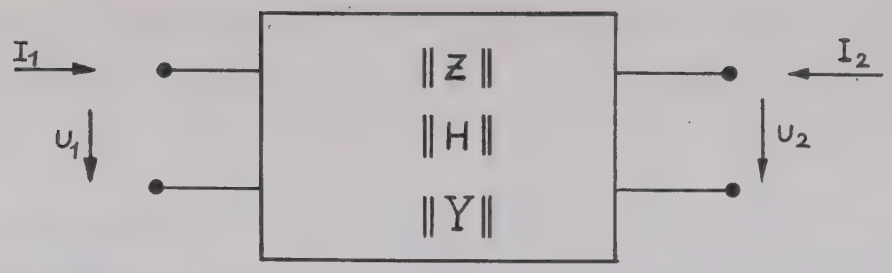


Fig. 12

From the values (U_1, U_2, I_1, I_2) various equations can be made up. Here we consider H, Y, and Z-parameters.

$$\begin{pmatrix} U_1 \\ U_2 \end{pmatrix} = \|Z_{\mu\nu}\| \begin{pmatrix} I_1 \\ I_2 \end{pmatrix} \qquad \left.\begin{aligned} U_1 &= Z_{11}\, I_1 + Z_{12}\, I_2 \\ U_2 &= Z_{21}\, I_1 + Z_{22}\, I_2 \end{aligned}\right\} \quad \text{Eq. 1}$$

$$\begin{pmatrix} U_1 \\ I_2 \end{pmatrix} = \|H_{\mu\nu}\| \begin{pmatrix} I_1 \\ U_2 \end{pmatrix} \qquad \left.\begin{aligned} U_1 &= H_{11}\, I_1 + H_{12}\, U_2 \\ I_2 &= H_{21}\, I_1 + H_{22}\, U_2 \end{aligned}\right\} \quad \text{Eq. 2}$$

$$\begin{pmatrix} I_1 \\ I_2 \end{pmatrix} = \|Y_{\mu\nu}\| \begin{pmatrix} U_1 \\ U_2 \end{pmatrix} \qquad \left.\begin{aligned} I_1 &= Y_{11}\, U_1 + Y_{12}\, U_2 \\ I_2 &= Y_{21}\, U_1 + Y_{22}\, U_2 \end{aligned}\right\} \quad \text{Eq. 3}$$

5.2 Determination of the Four-terminal Parameters

Here will be given the values to be measured and the formulae from which the transmission parameters are to be obtained.

5.2.1 Determination of the H-Parameters

As can be read from equation 2:

$$H_{11} = \left(\frac{U_1}{I_1}\right)_{U_2 = 0}$$ Input impedance with short circuit at the output

$$H_{22} = \left(\frac{I_2}{U_2}\right)_{I_1 = 0}$$ Output admittance when open circuited at the input

These values can be measured directly. The relative impedance Z/Z_0 (admittance Y/Y_0) can be read off the chart, and the impedance (the admittance Y) can be obtained by multiplication by Z_0 (Y_0). $Z_0 = \frac{1}{Y_0}$ equals the resistive characteristic impedance of the cable connector of the Diagraph.

Further more one requires the output admittance under short-circuit conditions $Y_{22} = \left(\frac{I_2}{U_2}\right)_{U_1 = 0}$

and also the forward transfer constant g_{BV}.

Source and load with resistive impedance Z_0 are given. Hence the transfer constant is $g_B = b_B + j \cdot a_B$

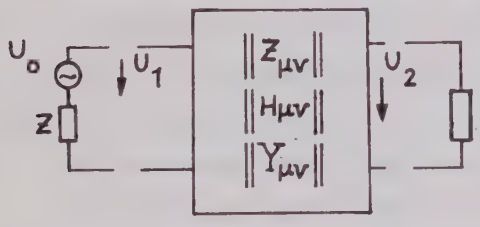


Fig. 13

Eq.4

$$g_B = \ln\left|\frac{U_0}{2U_2}\right| + j\varphi \quad \{N; arc\}$$

$$g_B = 20.\log\left|\frac{U_0}{2U_2}\right| + j\varphi \quad \{dB; arc\} \qquad \text{Eq. 4}$$

and the transmission factor

$$\ddot{U}_B = \exp\{g_B\} = \exp\{b_B\} + j \cdot a_B = \frac{U_0}{2U_2}$$

Measure the values: $H_{11}, H_{22}, Y_{22}, g_{BV}$ as described in 4 and determine H_{21} and H_{12} from the equations Eq. 5, Eq. 6.

$$H_{21} = -\frac{1}{2} \cdot \frac{1}{\ddot{U}_{Bv}}\left(1 + \frac{H_{11}}{Z_0} + H_{22} \cdot Z_0 + H_{11} \cdot Y_{22}\right) \qquad \text{Eq.5}$$

$$H_{12} = H_{11}\,\frac{(H_{22} - Y_{22})}{H_{21}} \qquad \text{Eq.6}$$

Since in this way one gets a difference of two similar values, the values H_{12} from the backward transfer constant which has to be measured separately.

$$H_{12} = \frac{1}{2} \cdot \frac{1}{\ddot{U}_{Br}} \cdot \left(1 + \frac{H_{11}}{Z_0} + H_{22} \cdot Z_0 + H_{11} \cdot Y_{22}\right) \qquad \text{Eq.7}$$

Compare example 5.5.

Since the values measured are complex, evaluations from equations 5 and 7 are relatively long-winded. H_{22} and Y_{22} mostly are so small as compared to $(1 + H_{11}/Z_o)$ that one can use the formula

$$H_{21} \approx -\frac{1}{2} \cdot \frac{1}{\ddot{U}_{Bv}} \left(1 + \frac{H_{11}}{Z_o}\right) \quad \text{as a first approximation} \qquad \text{Eq. 8}$$

At higher frequencies equation 8 involves an error. This can be estimated by putting $H_{22} \approx Y_{22}$ and rewriting equation 8 as:

$$H_{21} \approx -\frac{1}{2} \cdot \frac{1}{\ddot{U}_{Bv}} \left(1 + \frac{H_{11}}{Z_o}\right)\left(1 + H_{22} \cdot Z_o\right) \qquad \text{Eq. 8a}$$

That means however, that $\frac{H_{22}}{Z_o}$ gives directly the magnitude of the error obtained when doing the calculation according to equation 8. Equation 8a can be used for the second approximation for the determination of H_{12}, H_{21} but it should be made sure that H_{22} does not differ too much from Y_{22}. On the measurements which have been made up to now, the error obtained by using Eq. 8a as compared to using the accurate formula was smaller than 3.5%, even when measuring transistors far beyond their limiting frequency. This, however, holds only for grounded emitters or grounded base connection. Similar approximations can be made for the Y and Z -parameters.

5.2.2 Determination of the Y-Parameters

One measures:

$Y_{11} = \left(\frac{I_1}{U_1}\right) U_2 = 0$ — input admittance with short circuit at the output

$Y_{22} = \left(\frac{I_2}{U_2}\right) U_1 = 0$ — output admittance with short circuit at the input

$H_{22} = \left(\frac{I_2}{U_2}\right) I_1 = 0$ — output admittance with open circuit at the input

g_{Bv} i g_{Br} — transfer constant forward and backward, respective

From these values one calculates:

$$Y_{21} = -\frac{1}{2Z_o} \cdot \frac{1}{U_{Bv}} \left(1 + Y_{11} \cdot Z_o + Y_{22} \cdot Z_o + Y_{11} \cdot Z_o \cdot H_{22} \cdot Z_o\right) \qquad \text{Eq 9}$$

and:

$$Y_{12} = \frac{Y_{11}}{Y_{21}} \left(Y_{22} - H_{22}\right) \qquad \text{Eq. 10}$$

If the Y_{12} is to be measured more exactly, one uses backward transfer constant and obtains:

$$Y_{12} = -\frac{1}{2Z_o} \cdot \frac{1}{U_{Br}} \left(1 + Y_{11} \cdot Z_o + Y_{22} \cdot Z_o + Y_{11} \cdot Z_o \cdot H_{22} \cdot Z_o\right) \qquad \text{Eq. 11}$$

5.2.3 Determination of the Z-Parameters

The following are measured:

$Z_{11} = \left(\frac{U_1}{I_1}\right) I_2 = 0$ — input impedance with open circuit at the output

$Z_{22} = \left(\frac{U_2}{I_2}\right) I_1 = 0$ — output impedance with open circuit at the input

$H_{11} = \left(\frac{U_1}{I_1}\right) U_2 = 0$ — input impedance with open circuit at the output

g_{Bv}; g_{Br} — transfer constant forward and backward respectively

From these values one can obtain:

$$Z_{21} = \frac{Z_o}{2} \cdot \frac{1}{U_{Br}} \left(1 + \frac{Z_{11}}{Z_o} + \frac{Z_{22}}{Z_o} + \frac{H_{11}}{Z_o} \cdot \frac{Z_{22}}{Z_o}\right) \qquad \text{Eq. 12}$$

and

$$Z_{12} = \frac{Z_{22}}{Z_{21}} \left(Z_{11} - H_{11}\right)$$

If Z_{12} is to be measured more exactly, measure g_{Br}; then:

$$Z_{12} = \frac{Z_o}{2} \cdot \frac{1}{U_{Br}} \left(1 + \frac{Z_{11}}{Z_o} + \frac{Z_{22}}{Z_o} + \frac{H_{11}}{Z_o} \cdot \frac{Z_{22}}{Z_o}\right) \qquad \text{Eq. 13}$$

5.3 Conversion of the Individual Types of Parameters

$$\|Y_{\mu\nu}\| = \frac{1}{|Z|}\begin{Vmatrix} Z_{22} & -Z_{12} \\ -Z_{21} & Z_{11} \end{Vmatrix} = \frac{1}{H_{11}}\begin{Vmatrix} 1 & -H_{12} \\ H_{21} & |H| \end{Vmatrix} \qquad \text{Eq. 14}$$

$$\|Z_{\mu\nu}\| = \frac{1}{|Y|}\begin{Vmatrix} Y_{22} & -Y_{12} \\ -Y_{21} & Y_{11} \end{Vmatrix} = \frac{1}{H_{22}}\begin{Vmatrix} |H| & H_{12} \\ -H_{21} & 1 \end{Vmatrix} \qquad \text{Eq. 15}$$

$$\|H_{\mu\nu}\| = \frac{1}{Z_{22}}\begin{Vmatrix} |Z| & Z_{12} \\ -Z_{21} & 1 \end{Vmatrix} = \frac{1}{Y_{11}}\begin{Vmatrix} 1 & -Y_{12} \\ Y_{21} & |Y| \end{Vmatrix} \qquad \text{Eq. 16}$$

where

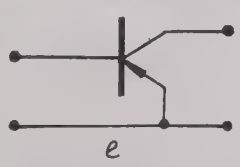
$$\alpha \begin{Vmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{Vmatrix} \equiv \begin{Vmatrix} \alpha H_{11} & \alpha H_{12} \\ \alpha H_{21} & \alpha H_{22} \end{Vmatrix}$$

and

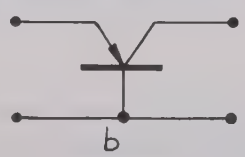
$$|H| \equiv H_{11} \quad H_{22} - H_{12} \cdot H_{21}$$

5.4 Conversion of the Parameters of one Connection into those of other Connections

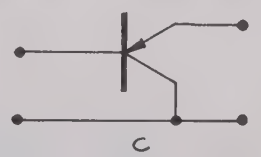
Similarly to valves, transistors are used in three connections, namely grounded-emitter, grounded-base and grounded-collector connection.



Grounded emitter
subscript 2



Grounded base
subscript b



Grounded collector
subscript c

The following are the conversion formulae for "H" and "Y" parameters.

$$Y_{11e} = Y_{11b} + Y_{12b} + Y_{21b} + Y_{22b}$$

$$Y_{12e} = -(Y_{12b} + Y_{22b})$$

$$Y_{21e} = -(Y_{21b} + Y_{22b}) \qquad \text{Eq. 17}$$

$$Y_{22e} = Y_{22b}$$

$$Y_{11b} = Y_{11e} + Y_{12e} + Y_{21e} + Y_{22e}$$

$$Y_{12b} = -\left(Y_{12e} + Y_{22e}\right)$$

$$Y_{21b} = -\left(Y_{21e} + Y_{22e}\right)$$

$$Y_{22b} = Y_{22e}$$

Eq. 18

$$Y_{11c} = Y_{11b} + Y_{12b} + Y_{21b} + Y_{22b}$$

$$Y_{12c} = -\left(Y_{11b} + Y_{21b}\right)$$

$$Y_{21c} = -\left(Y_{11b} + Y_{12b}\right)$$

$$Y_{22c} = Y_{11b}$$

Eq. 19

$$H_{11e} = \frac{H_{11b}}{|H_b| - H_{12b} + H_{21b} + 1}$$

$$H_{12e} = \frac{|H_b| - H_{12b}}{|H_b| - H_{12b} + H_{21b} + 1}$$

$$H_{21e} = \frac{-|H_o| - H_{21b}}{|H_b| - H_{12b} + H_{21b} + 1}$$

$$H_{22e} = \frac{H_{22b}}{|H_b| - H_{12b} + H_{21b} + 1}$$

Eq. 20

$$H_{11b} = \frac{H_{11e}}{|H_e| - H_{12e} + H_{21e} + 1}$$

$$H_{12b} = \frac{|H_e| - H_{12e}}{H_e - H_{12e} + H_{21e} + 1}$$

$$H_{21b} = \frac{-H_{21e} - |H_e|}{|H_e| - H_{12e} + H_{21e} + 1}$$

$$H_{22b} = \frac{H_{22e}}{|H_e| - H_{12e} + H_{21e} + 1}$$

Eq. 21

5.5 Example: -Parameter

For a transistor OC 171 the following values have been measured at 300 Mc.

$H_{11b/z_o} = 0{,}495 + j \cdot 0{,}16$ $\qquad H_{11b} = 29{,}6 + j \cdot 9{,}59\ \Omega$

$H_{22b.z_o} = 0{,}028 + j \cdot 0{,}31$ $\qquad H_{22b} = 0{,}466 + j \cdot 5{,}17\ mS$

$Y_{22b.z_o} = 0{,}044 + j \cdot 0{,}275$ $\qquad Y_{22b} = 0{,}732 + j \cdot 4{,}58\ mS$

$b_{Bv} = 9{,}25\ dB \quad 178^\circ$ $\qquad \frac{1}{\ddot{U}_{Bv}} = 0{,}3455 \quad \underline{/-178^\circ}$

$b_{Br} = 24{,}1\ dB \quad 247^\circ$ $\qquad \frac{1}{\ddot{U}_{Br}} = -0{,}0621 \quad \underline{/-247^\circ}$

From

$$H_{21} = -\frac{1}{2} \cdot \frac{1}{\ddot{U}_{Bv}} \left\{ 1 + \frac{H_{11}}{z_o} + H_{22} \cdot z_o + H_{11} \cdot Y_{22} \right\} \qquad \text{Eq. 5}$$

one obtains

$$H_{21} = -\frac{1}{2} \cdot 0{,}3455 \ \underline{/-178^\circ} \ (1 + 0{,}495 + j \cdot 0{,}16 + 0{,}025 + j \cdot 0{,}31 + (0{,}495 + j \cdot 0{,}16)(0{,}044 + j \cdot 0{,}275)$$

$$H_{21} = -0{,}1728 \ \underline{/-178^\circ} \ (1{,}501 + j \cdot 0{,}613)$$

$$= 0{,}1728 \cdot 1{,}634 \cdot \underline{/-178^\circ} \cdot \underline{/22{,}2^\circ} = 0{,}2824 \cdot \underline{/180^\circ - 178^\circ + 22{,}2^\circ}$$

$$= 0{,}2824 \ / 24{,}2^\circ$$

and from

$$H_{12} = \frac{1}{2} \cdot \frac{1}{\ddot{U}_{Br}} \left\{ 1 + \frac{H_{11}}{z_o} + H_{22} \cdot z_o + H_{11} \cdot Y_{22} \right\} \qquad \text{Eq. 7}$$

$$H_{12} = \frac{1}{2} \cdot 0{,}0621 \ \underline{/-247^\circ} \cdot 1{,}634 \ \underline{/22{,}2^\circ} = 0{,}0504 \ \underline{/360^\circ - 247^\circ + 22{,}2^\circ}$$

$$= 0{,}0504 \underline{/137{,}2^\circ}$$

For evaluation the following charts are used:
Amplitude-phase Chart, Reflection Coefficient Chart and Smith Chart, especially to convert

$$r \cdot \exp(j\varphi) \rightleftarrows \alpha + jb$$

and

$$(dB; \varphi) \rightleftarrows 10^{-\frac{dB}{20}} \angle -\varphi$$

The evaluation is preferably made in the form of a table. For the values calculated above, this is as follows:

Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Quantity	H_{11}/Z	$Y_{22} \cdot Z_0$	$H_{11} \cdot Y_{22}$	$H_{11} \cdot Y_{22}$	H_{11}/Z_0	$H_{22} \cdot Z_0$	( )	( )	b_{Bv}	$1/\ddot{u}_B$	H_{21}	b_{Br}	$1/\ddot{u}_B$	H_{12}
Unit	r φ	r φ	r φ	a b	a b	a b	a b	r φ	dB φ	r φ	r φ	dB φ	r φ	r φ
Value	0,52 17,9°	0,278 80,9°	0,138 98,8°	-0,0131 0,136	0,495 0,16	0,029 0,31	1,501 0,613	1,634 22,2°	9,25 17,8°	0,346 -178°	0,282 24,2°	24,14 247°	0,0621 -247°	0,0504 137,2°

For the other parameters similar tables can be set up.

6. Using Four-terminal Parameters for Calculation of Values of Interest in the Design of Transistor Circuits

6.1 Input Impedance Z_1 as a Function of the Output Impedance Z_2 (Y_2)

$$Z_1 = H_{11} - \frac{H_{12} \cdot H_{21}}{H_{22} + Y_2} = Z_{11} - \frac{Z_{12} \cdot Z_{21}}{Z_{22} + Z_2} = \frac{1}{Y_{11} - \frac{Y_{12}\, Y_{21}}{Y_{22} + Y_2}} \qquad \text{Eq.22}$$

6.2 Optimum Output Admittance Y_2

$$Y_{2\,opt.} = G_2 + jB_2 = G_{22} \sqrt{1 - \varrho - \frac{\sigma^2}{4}} + j\left(-B_{22} + G_{22} \cdot \frac{\sigma}{2}\right) \qquad \text{Eq.23}$$

where

$$\varrho = Re \left\{ \frac{Y_{12}\ Y_{21}}{G_{11}\ G_{22}} \right\} \qquad \sigma = Im \left\{ \frac{Y_{12} \cdot Y_{21}}{G_{11} \cdot G_{22}} \right\} \qquad \text{Eq.24}$$

and

$$Y_{\mu v} = G_{\mu v} + j \cdot B_{\mu v} \qquad Y_V = G_v + j \cdot B_v$$

6.3 Power Amplification v_N as a Function of the Output Admittance

$$v_N = \left|\frac{Z_{21}}{Y_2 \cdot |Z| + Z_{11}}\right|^2 \cdot \frac{G_2}{G_1} = \left|\frac{Y_{21}}{Y_{22} + Y_2}\right|^2 \cdot \frac{G_2}{G_1} = \left|\frac{H_{21}}{|H| + H_{11} \cdot Y_2}\right| \frac{G_2}{G_1} \qquad \text{Eq. 25}$$

6.4 Optimum Power Amplification

$$v_{N\,opt.} = \frac{|Y_{21}|^2}{4 G_{11} G_{22}} \cdot \frac{1}{\Phi}$$

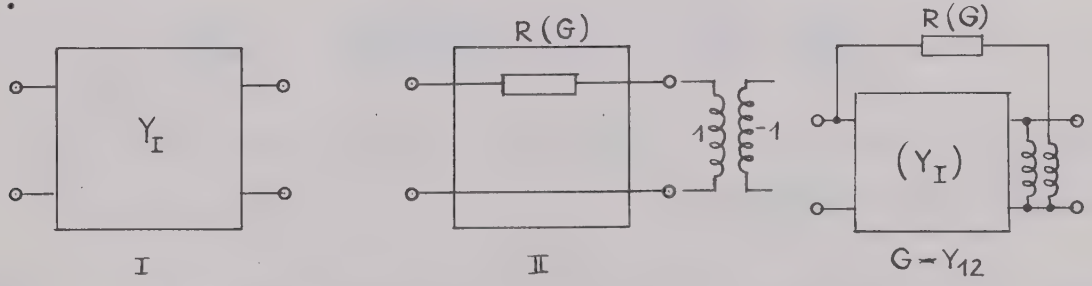
where

Eq. 26

$$\Phi = \frac{1}{2}\left(1 - \frac{\varrho}{2} + \sqrt{1 - \varrho - \frac{\sigma^2}{4}}\right)$$

6.5 Neutralization and Stability

Before using transistors at higher frequencies the problem of neutralization has to be solved. The barrier layer is thin in all HF transistors and therefore the feedback must not be neglected at higher frequencies. Should the product of amplification times feedback be larger than one, the amplifier might become unstable. At higher frequencies the neutralization admittance has generally an active component, that is to say it uses power and alters the transistor parameters if Y_{12} is no longer small against Y_{11} or Y_{22}. The four-terminal network II is connected in parallel to the transistor I via a matching unit with the transformation ratio of 1:-1.



G or R is is so chosen that Y_{12} equals 0. Then the Y parameters of the four-terminal network are:

$$(Y)_{neutr} = \left\| \begin{matrix} Y_{11} + G & 0 \\ Y_{21} + G & Y_{22} + G \end{matrix} \right\| \qquad \text{Eq. 27}$$

As the forward transfer admittance decreases, the transistor is, as every other network, stable. If the neutralization is not complete, a stability criterion is required, which, being a function of circuit and transistor parameters, permits the safety against the starting of oscillations to be determined. It is difficult to set up a strict stability criterion; for practical use it is sufficient to demand that the product of the voltage amplification forward and amplification backward be smaller than 1.

$$\left| \frac{Y_{12} \cdot Y_{21}}{(Y_{11} + Y_1)(Y_{22} + Y_2)} \right| < 1 \qquad \text{Eq. 28}$$

An example for the dimensioning of narrow-band amplifiers by means of four-terminal parameters is given in (1) and an investigation of stability and power amplification of a band-pass-filter-coupled transistor amplifier in (2).

References:

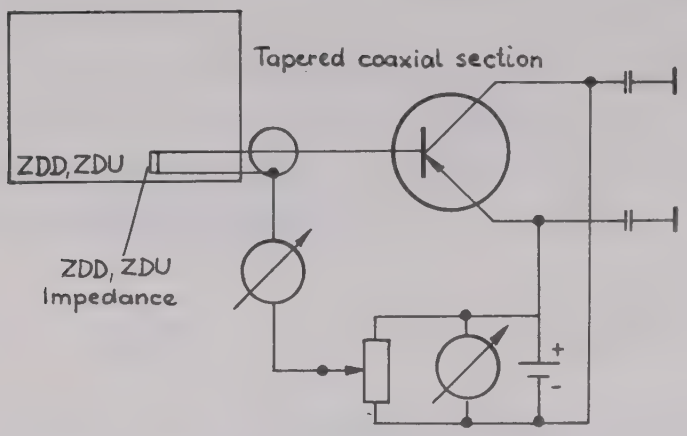
(1) Ein AM-FM-Empfänger mit Transistoren, Technische Informationen für die Industrie, H. 21 H, Valvo, Hamburg

An AM-FM receiver with transistors, Technical Information for the Industry, H. 21 H, Valvo, Hamburg

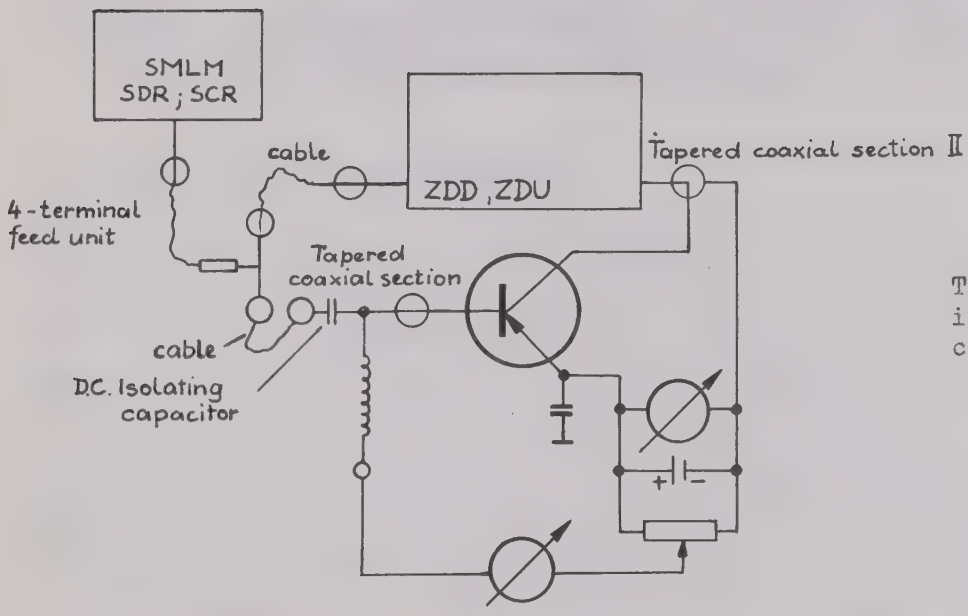
(2) F. Weitzsch, Einige theoretische Untersuchungen zur Leistungsübertragung und Stabilität in transistorbestückten ZF-Verstärkern bei Verwendung von Bandfiltern. Technische Informationen für die Industrie, Sonderdruck, Valvo, Hamburg

F. Weitzsch, Some theoretical investigation for power transmission and stability in transistorized IF amplifiers when using band-pass filters. Technical Information for the Industry, Valvo, Hamburg

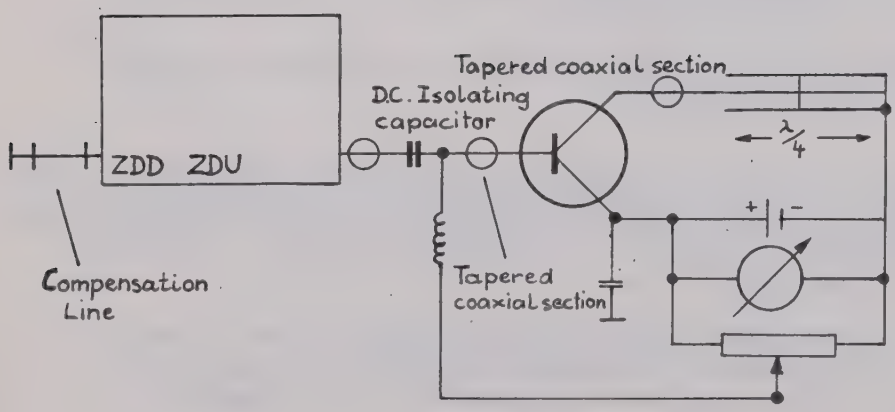
Circuit for Connecting DC Supply



Measurement of the base input impedance with short-circuited output H_{11e}



Transfer constant in grounded-emitter connection g_{Be}



Adjustable short

Measurement of the input impedance with open-circuited collector $\overline{Z}_{11e}$

Meaning of the Symbols Used

Symbol	Equivalent to	measured in	Designation
H_{11}	$(u_1/\mathfrak{J}_1)_{u_2=0}$	Ω	Short-circuit output, input impedance
H_{12}	$(u_1/\mathfrak{J}_2)_{\mathfrak{J}_1=0}$	1	Input open circuited, voltage transformation backwards
H_{21}	$(\mathfrak{J}_2/\mathfrak{J}_1)_{u_2=0}$	1	Output short circuit, current transformation forward
H_{22}	$(\mathfrak{J}_2/u_1)_{\mathfrak{J}_1=0}$	S	Input open circuited, output admittance
Z_{11}	$(u_1/\mathfrak{J}_1)_{\mathfrak{J}_2=0}$	Ω	Output open circuited, input resistance (impedance)
Z_{12}	$(u_1/\mathfrak{J}_2)_{\mathfrak{J}_1=0}$	Ω	Input open circuited, transmission resistance backward
Z_{21}	$(u_2/\mathfrak{J}_1)_{\mathfrak{J}_2=0}$	Ω	Output open circuited, transmission resistance forward
Z_{22}	$(u_2/\mathfrak{J}_2)_{\mathfrak{J}_1=0}$	Ω	Input open circuited, output resistance
Y_{11}	$(\mathfrak{J}_1/u_1)_{u_2=0}$	S	Output short-circuit, input admittance
Y_{12}	$(\mathfrak{J}_1/u_2)_{u_1=0}$	S	Input short circuit, transmission admittance backward
Y_{21}	$(\mathfrak{J}_2/u_1)_{u_2=0}$	S	Output short circuit, transmission admittance forward
Y_{22}	$(\mathfrak{J}_2/u_2)_{u_1=0}$	S	Input short circuit, output admittance
Z_1	$1/Y_1$	Ω	Input impedance of the transistor
Z_2	$1/Y_2$	Ω	Terminating impedance of the transistor
Z_0	$1/Y_0$	Ω	Characteristic impedance, reference impedance
g_{Bv}	$b_{Bv}+j\cdot a_{Bv}$	1	Transfer constant forward
g_{Br}	$b_{Br}+j\cdot a_{Br}$	1	Transfer constant backward
$\ddot{u}_B$	ℓ^{gB}	1	Operational transmission factor
G	$1/R$	S	Neutralization admittance
V_N		1	Power amplification
$Y_{\mu v}$	$G_{\mu v}+j\cdot B_{\mu v}$	S	Admittance parameter
$\alpha;\beta;\sigma;\varphi$			Abbreviations

Supplement

to Instruction Book R 6835 a

TRANSISTOR ADAPTOR AND ACCESSORIES

BN 35616

Edition R 8987/364

(Translation of the German edition R 8840/264)

R 8987
364
Bl. 1
(12 Bl.)

Re Chapter 4:

Chapter 4 of the instruction book for the Transistor Adaptor concerns the measurements. In this respect the test setup, i. e. the connection of the Adaptor to the measuring instrument and to the DC voltage source, is of importance. Once the principle of the measurement is clear, it is easy to find the appropriate test setup. There often exist several possibilities.

In practice it is tedious to have to think about how to connect the Transistor Adaptor before each measurement or series of measurements. It is simpler to find the necessary information on a table or drawing. For this reason tables and drawings for the base, emitter and collector circuits are provided on the following pages. The tables show the connections for the measurement of the impedance and admittance parameters; the connections for measuring the transmission parameters can be determined from the drawings.

The type of measurement is entered in column 1 of the tables. Columns 2, 3 and 4 indicate where the emitter, base and collector wires of the transistor being measured are to be connected. The references are explained below. The columns 5, 6 and 7 contain mainly figures. These indicate the pin of the Tuchel-type connector to which the line I, II or III is to be connected. The lines are identified by the sketches below the tables. The position of the pins of the Tuchel-type connector can be seen in Fig. 3 on page 8 of the instruction book for the Transistor Adaptor. The Coaxial Reference Line to be used (10 cm or 20 cm long) is specified in column 8; column 9 indicates whether the DC Feed Section is to be used or not.

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Bl. 2

References used in the tables and drawings:

M I	tapered coaxial section of Transistor Adaptor
M II	tapered coaxial section of Transistor Adaptor
F 2	contact springs wiping on capacitor plate 2
F 4	contact springs wiping on capacitor plate 4
KL 10	coaxial reference line 10 cm in length
KL 20	coaxial reference line 20 cm in length
Glz	coaxial DC feed section
RL	calibrated adjustable short
MK	coaxial test line of Type ZDU or ZDD

Remarks referring to the drawings:

The polarity of the voltage source (0-1.5 v and 0-30 v) as shown in the drawings applies to pnp transistors. It must be reversed for measuring npn transistors. The circuits shown in the drawings measure the forward effective transmission factor g_{Bv}. Only the connections 1-1 and 2-2 are to be interchanged for measuring the backward effective transmission factor g_{Br}. The lines marked K mean coaxial cables having equal electrical length and a characteristic impedance corresponding with that of the Type ZDU or ZDD and of the Transistor Adaptor.

The Low-Voltage Power Supply Type NGN is recommended as DC power source. It presents high stability and is particularly suitable for feeding transistors. It supplies two independent floating voltages, continuously adjustable from 0 to 30 v and 0 to 1.5 v, respectively.

Table 1

Base circuit

Type of measurement (parameter)	Transistor connections			DC voltage connection e b c			Coaxial reference line to be used in the reference branch	Use of coaxial DC feed section
	Emitter	Base	Collector	I	II	III		
1	2	3	4	5	6	7	8	9
h_{11}	M I M K	F 2	F 4	5	2	4	KL 10	no
h_{12} h_{21}	Measurement of g_{Bv} and g_{Br} according to Fig. 1 Calculation of h_{12} and h_{21} according to eq. 7 and 5 (p.15 of instruction book)							
h_{22}	M II RL	F 2	M I Glz M K	5	2	Glz	KL 20	yes
y_{11}	same as for h_{11}							
y_{12} y_{21}	Measurement of g_{Bv} and g_{Br} according to Fig. 1 Calculation of y_{12} and y_{21} according to eq. 11 and 9 (p. 17 of instruction book)							
y_{22}	F 4	F 2	M I M K	4	2	5	KL 10	no
Z_{11}	M I Glz M K	F 2	M II RL	Glz	2	5	KL 20	yes
Z_{12} Z_{21}	Measurement of g_{Bv} and g_{Br} according to Fig. 1 Calculation of Z_{12} and Z_{21} according to eq. 13 and 12 (p. 17 of instruction book)							
Z_{22}	same as for h_{22}							

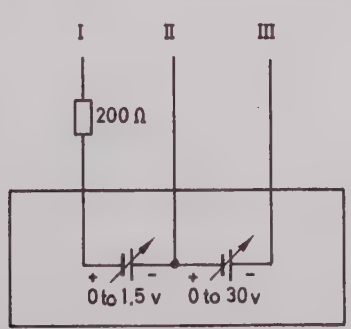

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Table 2

Emitter circuit

Type of measurement (parameter)	Transistor connections			DC voltage connection			Coaxial reference line to be used in the reference branch	Use of coaxial DC feed section
	Emitter	Base	Collector	e	b	c		
				I	II	III		
1	2	3	4	5	6	7	8	9
h_{11}	F 2	M I M K	F 4	2	5	4	KL 10	no
h_{12} h_{21}	Measurement of g_{Bv} and g_{Br} according to Fig. 2 Calculation of h_{12} and h_{21} according to eq. 7 and 5 (p. 15 of instruction book)							
h_{22}	F 2	MII Glz RL	M I M K	2	Glz	5	KL 20	yes
y_{11}	same as for h_{11}							
y_{12} y_{21}	Measurement of g_{Bv} and g_{Br} according to Fig. 2 Calculation of y_{12} and y_{21} according to eq. 11 and 9 (p. 17 of instruction book)							
y_{22}	F 2	F 4	M I M K	2	4	5	KL 10	no
Z_{11}	F 2	MI Glz M K	MII RL	2	Glz	5	KL 20	yes
Z_{12} Z_{21}	Measurement of g_{Bv} and g_{Br} according to Fig. 2 Calculation of Z_{12} and Z_{21} according to eq. 13 and 12 (p. 17 of instruction book)							
Z_{22}	same as for h_{22}							

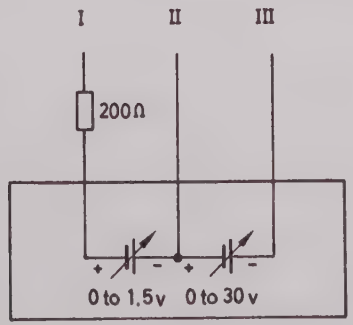

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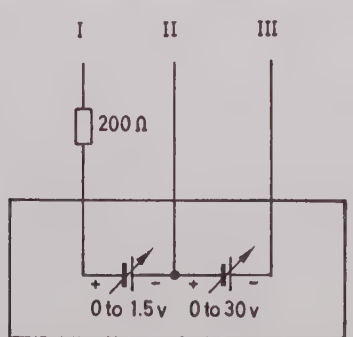
Table 3

Collector circuit

Type of measurement (parameter)	Transistor connections			DC voltage connection			Coaxial reference line to be used in the reference branch	Use of coaxial DC feed section
	Emitter	Base	Collector	e	b	c		
1	2	3	4	I 5	II 6	III 7	8	9
h_{11}	F 4	M I M K	F 2	4	5	2	KL 10	no
h_{12} h_{21}	Measurement of g_{Bv} and g_{Br} according to Fig. 3 Calculation of h_{12} and h_{21} according to eq. 7 and 5 (p. 15 of instruction book)							
h_{22}	M I M K	M II RL Glz	F 2	5	Glz	2	KL 10	yes
y_{11}	same as for h_{11}							
y_{12} y_{21}	Measurement of g_{Bv} and g_{Br} according to Fig. 3 Calculation of y_{12} and y_{21} according to eq. 11 and 9 (p. 17 of instruction book)							
y_{22}	M I M K	F 4	F 2	5	4	2	KL 10	no
Z_{11}	M I Glz RL	M II MK	F 2	Glz	5	2	KL 10	yes
Z_{12} Z_{21}	Measurement of g_{Bv} and g_{Br} according to Fig. 3 Calculation of Z_{12} and Z_{21} according to eq. 13 and 12 (p. 17 of instruction book)							
Z_{22}	same as for h_{22}							



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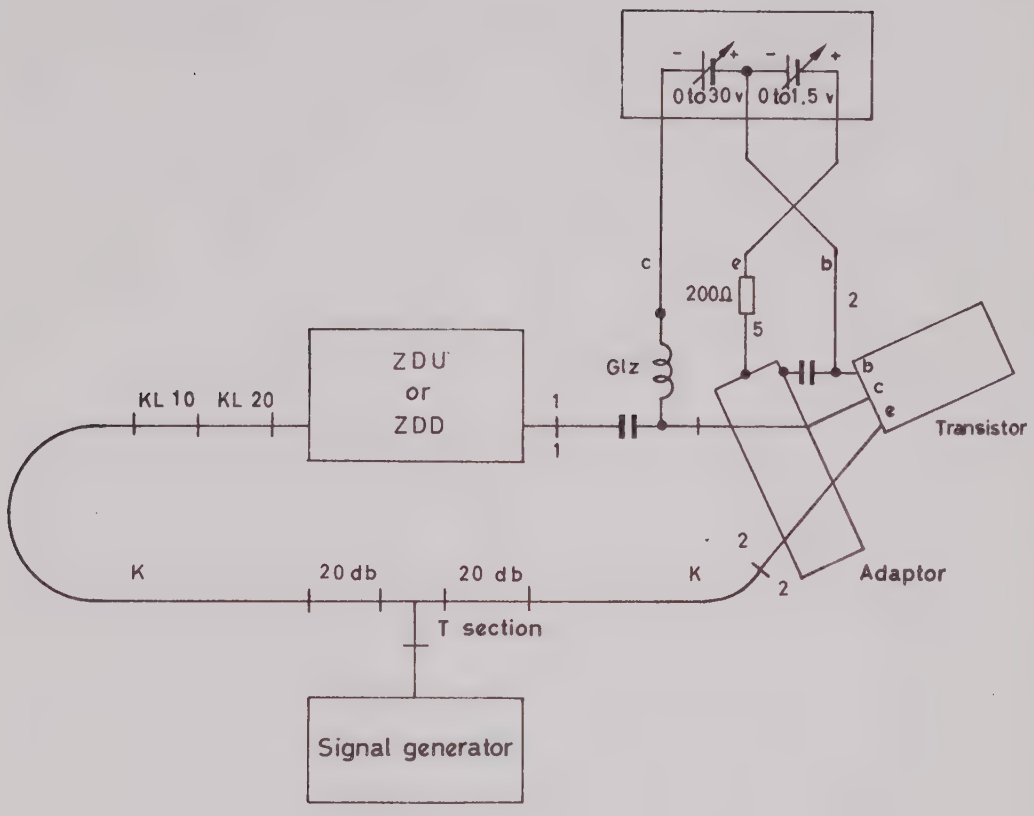

Fig. 1

Measuring the effective transmission factor g_{Bv} in a base circuit

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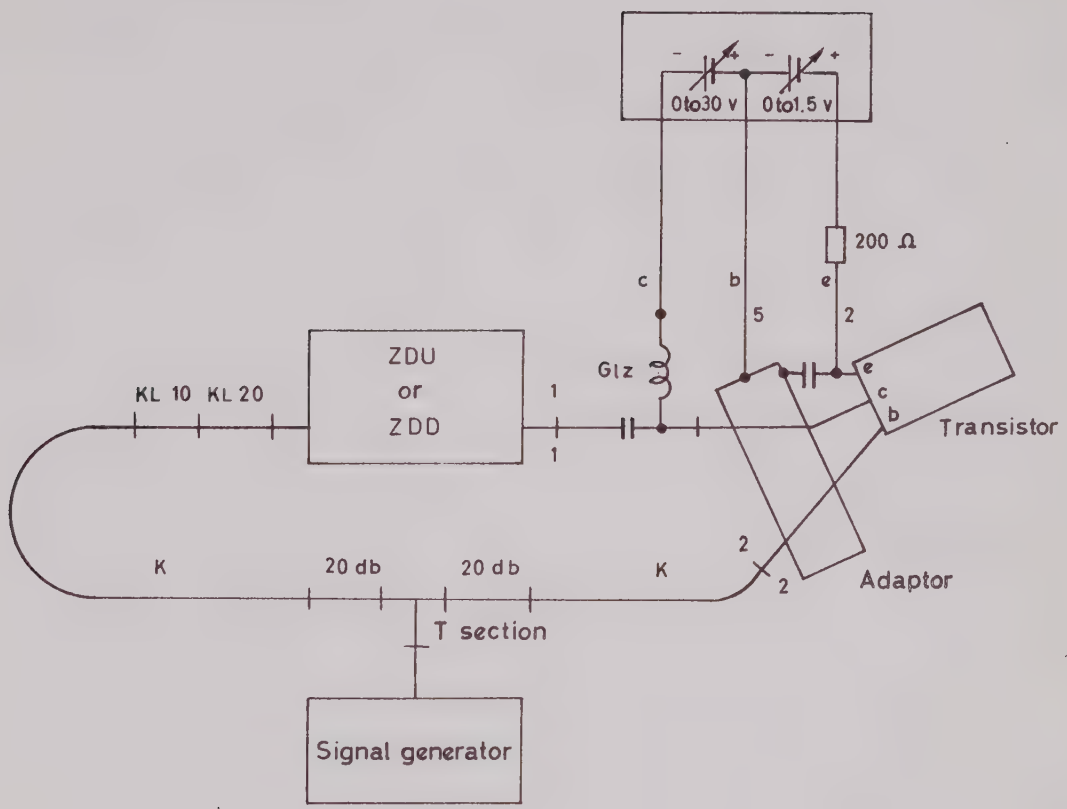

Fig. 2

Measuring the effective transmission factor g_{Bv}

in an emitter circuit

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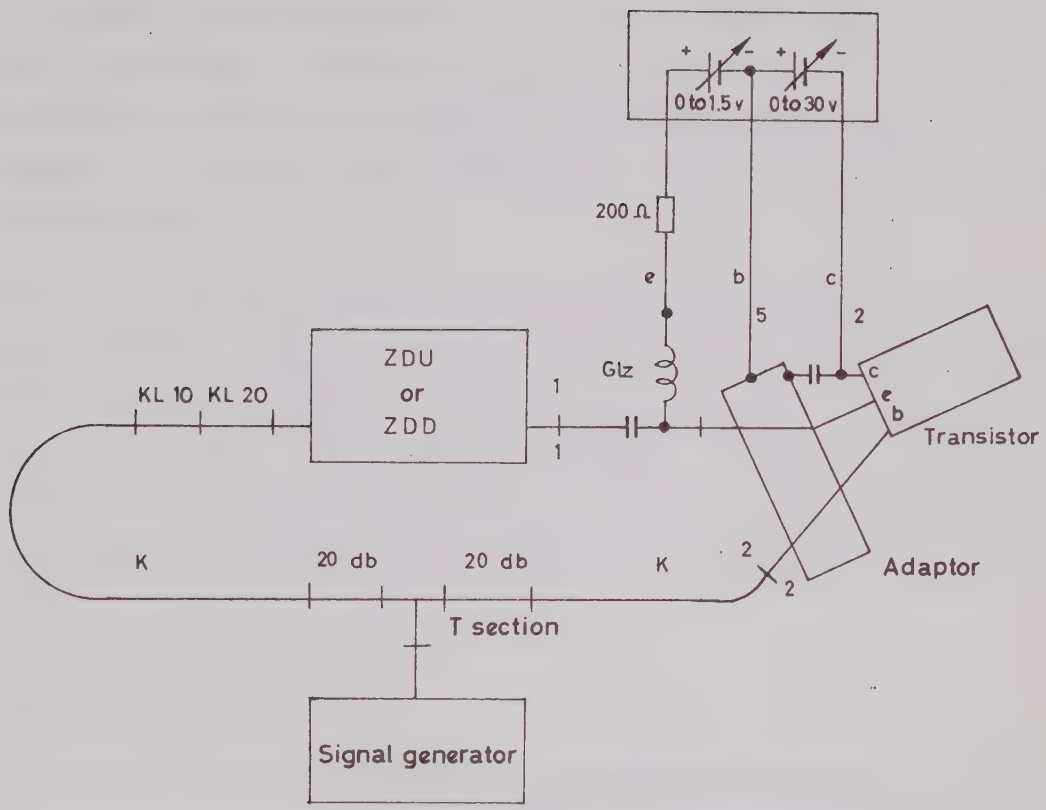

Fig. 3

Measuring the effective transmission factor g_{Bv} in a collector circuit

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Re Section 4.3.2:

Transistors are amplifying elements. When considered as a four-terminal network, the transistor may be said to present negative attenuation. When the effective transmission factor is measured with a Z-g Diagraph, the negative attenuation causes the light spot of the galvanometer to move outside the 0-db circle (full deflection). Thus it is not possible to read the attenuation.

There are two methods which nevertheless permit an attenuation measurement. The first method is to adjust the Z-g Diagraph to 0° and 0 db while the indication is switched to spread and to make the measurement with normal indication. This method is practicable as long as the negative attenuation of the test item does not exceed 9.54 db. Either the four-terminal feed unit or a T section and two 20-db attenuator pads may be used for feeding.

Procedure:

(a) Connect the four-terminal feed unit without test item to the inputs of the Z-g Diagraph via two coaxial cables of equal electrical length.

(b) Switch the Z-g Diagraph to spread indication.

(c) Adjust the signal-generator voltage so that the galvanometer light spot stands on the 0-db circle (full deflection). Adjust phase. Do not change the signal voltage any more.

(d) Switch the Z-g Diagraph to normal indication. The light spot is now at 1/3 of the chart radius (9.54 db).

(e) Insert the Transistor Adaptor and the DC separation into the path of the coaxial test line; insert the appropriate compensation lengths into the path of the coaxial reference line.

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(f) Make the phase adjustment, read attenuation b'_B.

(g) To find the unknown value b_B add the reading b'_B to -9.54 db. The minus sign results from the negative attenuation.

Thus

$$b_B = -9.54 + b'_B$$

(h) Read the phase angle from the chart.

Numerical example:

Readings: $b'_B = 3.54$ db; $\varphi = 23^\circ$

The attenuation constant is then

$$\begin{aligned} b_B &= -9.54 + b'_B \\ &= -9.54 + 3.54 \\ &= -6 \text{ db} \end{aligned}$$

The effective transmission factor is

$$\begin{aligned} u_B &= 10^{\frac{b}{20}} \\ &= 10^{\frac{-6}{20}} \times \angle 23^\circ \\ &= 0.5 \times \angle 23^\circ \end{aligned}$$

The second method consists in interchanging the coaxial test line and the coaxial reference line of the Z-g Diagraph. This method is also suitable for higher gains. The voltage is to be fed in via a T section x) and two 20-db attenuators (BN 18062/50 or 18062/60).

x) Three types of T-section are available:

for Z = 50 Ω FS 532/50
Z = 60 Ω FS 532
Z = 75 Ω FS 532/75

Procedure:

(a) Connect the T-section with two 20-db attenuators to the inputs of the Z-g Diagraph via two coaxial cables of equal electrical length.

(b) Adjust the Z-g Diagraph, switched to normal indication, with respect to magnitude and phase. Set reference meter to "100".

(c) Insert the Transistor Adaptor and the DC separation into the path of the coaxial reference line; insert the suitable compensation lengths into the path of the coaxial test line.

(d) Reduce the signal-generator voltage so far that the reference meter indicates "100".

(e) Make the phase adjustment on the Z-g Diagraph. Read b_B and φ'.

The interchanging of the coaxial test line and the coaxial reference line results in a negative attenuation. Therefore the db reading is preceded by a minus sign for evaluation. The phase angle is

$$\varphi = 360^{\circ} - \varphi'$$

φ' being the angle read in the chart.

Numerical example:

Readings: $b_B = 6$ db

$\varphi' = 330^{\circ}$

Hence the phase angle is $360^{\circ} - 330^{\circ}$

$= 30^{\circ}$

and the attenuation constant is -6 db.

The effective transmission factor is thus

$$u_B = 10^{\frac{-6}{20}} \times \underline{/30^{\circ}}$$

$$= 0.5 \times \underline{/30^{\circ}}$$

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